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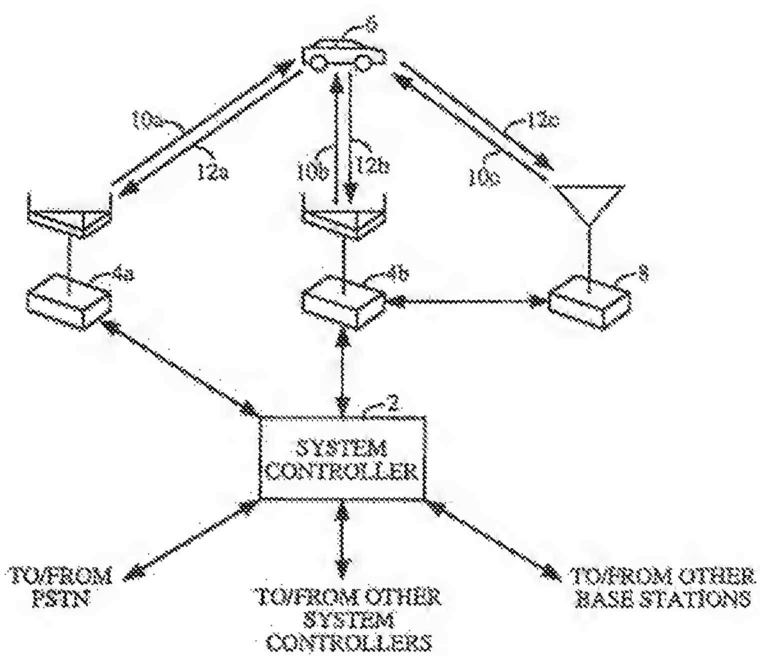
(57) Abstract



A method and apparatus for providing handoff between two communication systems. The systems can be CDMA systems operating at different frequencies or systems employing different technologies. In the first system, a base station (4) is configured to provide communications to two or more sectors, with at least one sector assigned to a corresponding repeater (8) which provides coverage overlapping that of both systems. As the remote station (6) moves into the coverage area of the repeater (8), the pilot signal of the repeater (8) is identified, measured and sent to the first system. If the measured pilot signal is above a predetermined add threshold, the repeater (8) is added to the active set of the remote station. The first system can handoff the remote station (6) to the second system: (1) upon initiation of a soft handoff by the base station of the first system; (2) if the pilot signal strength of the repeater (8), as measured by the remote station (6), exceeds a predetermined handoff threshold; (3) if the base station (4) of the first system is dropped from the active set of the remote station (6); (4) if the repeater of the first system is dropped from the active set of the remote station (6); or (5) if the base station (4) and repeater (8) of the first system are dropped from the active set of the remote station (6).

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METHOD AND APPARATUS FOR PERFORMING HANDOFF IN A CDMA SYSTEM THROUGH THE USE OF REPEATERS

BACKGROUND OF THE INVENTION

I. Field of the Invention

The present invention relates to communications. More particularly, the present invention relates to a method and apparatus for performing handoff in a CDMA system through the use of repeaters.

II. Description of the Related Art

The use of code division multiple access (CDMA) modulation techniques is one of several techniques for facilitating communications in a system with a large number of users. Although other techniques such as time division multiple access (TDMA), frequency division multiple access (FDMA), and AM modulation schemes such as amplitude companded single sideband (ACSSB) are known, CDMA has significant advantages over these other techniques. The use of CDMA techniques in a multiple access communication system is disclosed in U.S. Patent No. 4,901,307, entitled "SPREAD SPECTRUM MULTIPLE ACCESS COMMUNICATION SYSTEM USING SATELLITE OR TERRESTRIAL REPEATERS," assigned to the assignee of the present invention and incorporated by reference herein. The use of CDMA techniques in a multiple access communication system is further disclosed in U.S. Patent No. 5,103,459, entitled "SYSTEM AND METHOD FOR GENERATING SIGNAL WAVEFORMS IN A CDMA CELLULAR TELEPHONE SYSTEM", assigned to the assignee of the present invention and incorporated by reference herein. The CDMA system can be designed to conform to the "TIA/EIA/IS-95 Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System", hereinafter referred to as the IS-95 standard.

In the aforementioned U.S. Patent Nos. 4,901,307 and 5,103,459, a multiple access technique is disclosed in which a large number of mobile telephone system users, each having a transceiver (also known as a remote station), communicate through satellite repeaters or terrestrial base stations (also known as base stations or cell-sites) using CDMA spread spectrum communication signals. In using CDMA communications, the frequency spectrum can be reused in neighboring cell-sites. The use of CDMA techniques results in a higher spectral efficiency than can be achieved using

other multiple access techniques, thus permitting an increase in system user capacity.

As described herein, a base station is the physical hardware through which communications is conducted. A cell is the geographical coverage area within which communications with the base station is possible. A cell can be partitioned into multiple sectors, and the sectors can be overlapping or non-overlapping. In the exemplary CDMA communication system, each base station can support communications through multiple sectors. In this specification, sector and cell can also refer to the physical hardware through which communication is conducted, depending on the context in which the terms are used. A system refers to a set of base stations controlled by a common system controller.

The conventional FM cellular telephone systems used within the United States is commonly called the Advanced Mobile Phone Service (AMPS), and is detailed in the Electronic Industry Association standard EIA/TIA-553 "Mobile Station - Land Station Compatibility Specification". In such a conventional FM cellular telephone system, the available frequency band is divided into channels typically 30 KHz in bandwidth. The system service area is divided geographically into base station coverage areas which may vary in size. The available frequency channels are divided into sets. The frequency sets are assigned to the coverage areas in such a way as to minimize the possibility of co-channel interference. For example, consider a system in which there are seven frequency sets and the coverage areas are equally sized hexagons. The frequency set used in one coverage area is not used in the six nearest neighboring coverage areas.

In conventional cellular systems, a handoff scheme is used to allow a communication connection to continue when a remote station crosses the boundary between coverage areas of two different base stations. In the AMPS system, the handoff from one base station to another is initiated when the active base station handling the call determines that the received signal strength from the remote station has fallen below a predetermined threshold value. A low signal strength indication implies that the remote station is near the coverage area boundary of the base station. When the signal level falls below the predetermined threshold value, the active base station asks the system controller to determine whether a neighboring base station receives the remote station signal with better signal strength than the current base station.

The system controller, in response to the active base station inquiry, sends messages to the neighboring base stations with a handoff request.

Each of the base stations neighboring the active base station employs a special scanning receiver which looks for the signal from the remote station on the channel at which it is operating. Should one of the neighboring base stations reports an adequate signal level to the system controller, a handoff is attempted to that neighboring base station which is now referred to as the target base station. Handoff is then initiated by selecting an idle channel from the channel set used in the target base station. A control message is sent to the remote station directing it to switch from the current channel to the new channel supported by the target base station. At the same time, the system controller switches the call connection from the active base station to the target base station. This process is referred to as hard handoff. The term 'hard' is used to characterize the 'break-before-make' characteristic of the handoff.

In the conventional system, a call connection is dropped (i.e. discontinued) if the handoff to the target base station is unsuccessful. There are many reasons why a hard handoff failure may occur. First, handoff can fail if there is no idle channel available in the target base station. Second, handoff can also fail if one of the neighboring base stations reports receiving a signal from the remote station, when in fact the base station actually receives a signal from a different remote station which is using the same channel to communicate with a distant base station. This reporting error results in the transfer of the call connection to a wrong base station, typically one in which signal strength from the actual remote station is insufficient to maintain communications. And third, the handoff fails if the remote station fails to receive the command to switch channels. Actual operating experience indicates that handoff failures occur frequently which significantly lowers the reliability of the system.

Another common problem in the conventional AMPS telephone system occurs when the remote station remains for an extended period of time near the border between two coverage areas. In this situation, the signal level tends to fluctuate with respect to each base station as the remote station changes position, as other reflective or attenuative objects within the coverage area change position, or due to measurement uncertainty. The signal level fluctuations can result in a 'ping-ponging' situation wherein repeated requests are made to handoff the call back and forth between the two base stations. Such additional unnecessary handoffs increase the probability that the call is inadvertently discontinued. Furthermore, repeated handoffs, even if successful, can adversely effect signal quality.

In U.S. Patent No. 5,101,501, entitled "METHOD AND SYSTEM FOR PROVIDING A SOFT HANDOFF IN COMMUNICATIONS IN A CDMA CELLULAR TELEPHONE SYSTEM", issued March 31, 1992, assigned to the assignee of the present invention and incorporated by reference herein, a method and system are disclosed for providing communication with the remote station through more than one base station during the handoff of a CDMA call. Using this type of handoff, communication within the cellular system is uninterrupted by the handoff from the active base station to the target base station. This type of handoff may be considered as a 'soft' handoff in that concurrent communications is established with the target base station which becomes a second active base station before communication with the first active base station is terminated.

Another soft handoff technique is disclosed in U.S. Patent No. 5,267,261, entitled "MOBILE STATION ASSISTED SOFT HANDOFF IN A CDMA CELLULAR COMMUNICATIONS SYSTEM", issued November 30, 1993, assigned to the assignee of the present invention and incorporated by reference herein. In the system of U.S. Patent No. 5,267,261, the soft handoff process is controlled based on measurements at the remote station of the strength of the pilot signal transmitted by each base station within the system. These pilot strength measurements assist the soft handoff process by facilitating identification of viable base station handoff candidates.

More specifically, in the system of U.S. Patent No. 5,267,261, the remote station monitors the signal strength of pilot signals from neighboring base stations. The coverage area of the neighboring base stations need not actually abut the coverage area of the base station with which active communication is established. When the measured signal strength of the pilot signal from one of the neighboring base stations exceeds a predetermined add threshold, the remote station sends a signal strength message to a system controller via the active base station. The system controller directs a target base station to establish communication with the remote station and directs the remote station via the active base station to establish contemporaneous communication through the target base station while maintaining communication with the active base station. This process can continue for additional base stations.

When the remote station detects that the signal strength of a pilot corresponding to one of the base stations through which the remote station is communicating has fallen below a predetermined drop threshold, the remote station reports the measured signal strength of the corresponding

base station to the system controller via the active base stations. The system controller sends a command message to the identified base station and to the remote station to terminate communication with the identified base station while maintaining communications with other active base stations.

Although the foregoing techniques are well-suited for call transfers between base stations in the same cellular system which are controlled by the same system controller, a more difficult situation is presented by movement of the remote station into a coverage area serviced by a base station operating at a different frequency or by a base station of another cellular system. One complicating factor in an interfrequency and/or intersystem handoff is the inability to transmit and received signals at two frequencies simultaneously due to hardware limitations. Another complicating factor in the intersystem handoff is that each system is controlled by a different system controller and typically there is no direct link between the base stations of the first system and the system controller of the second system, and vice versa. The two systems are thereby precluded from providing simultaneous communication with the remote station during the handoff process. Even when the existence of an intersystem link between the two systems is available to facilitate intersystem soft handoff, dissimilar characteristics of the two systems often further complicate the soft handoff process.

When resources are not available to conduct interfrequency and/or intersystem soft handoffs, the execution of a 'hard' handoff of a call connection from one frequency to another frequency and/or from one system to another system becomes critical if uninterrupted service is to be maintained. The interfrequency and/or intersystem handoff should be executed at a time and location likely to result in successful transfer of the call connection between systems. The handoff should be attempted only when, for example:

(1) an idle channel is available in the target base station,

(2) the remote station is within range of the target base station and the active base station, and

(3) the remote station is in a position at which it is assured of receiving the command to switch channels.

Ideally, each such interfrequency and/or intersystem hard handoff should be conducted in a manner which minimizes the potential for 'ping-ponging' handoff requests between the base stations of different systems.

These and other shortcomings of existing interfrequency and intersystem handoff techniques impair the quality of cellular communications. Further degradation in performance can be expected as competing cellular systems continue to proliferate. Accordingly, there is a resulting need for an interfrequency and intersystem handoff technique capable of reliably executing the handoff of a call between the base stations.

SUMMARY OF THE INVENTION

The present invention is a method and apparatus for performing handoff between two communication systems through the use of repeaters. The systems can be CDMA systems operating at different frequencies or systems employing different technologies, such as CDMA and AMPS. In the exemplary embodiment, in the first system, the base station is configured to provide coverage to two or more sectors. One or more sectors is associated with the coverage area surrounding the base station, which is also referred to as the cell. The remaining one or more sectors is each associated with a respective repeater which is located at the boundary of the cell. Each repeater provide communications for a coverage area surrounding the respective repeater.

In the exemplary embodiment, the coverage area of the repeater overlaps the cell of the first system such that handoff can be performed between the base station and the repeater. In the exemplary embodiment, the coverage area of the repeater also overlaps a cell of the second system such that handoff can be performed between the base station or repeater of the first system and a base station (or a repeater) of the second system.

In the exemplary embodiment, the pilot signals of the base station and repeater of the first system are distinguished by different offsets of the common short PN spreading codes which are used to spread the data. Alternatively, the pilot signals can be distinguished by different Walsh covers, or other identifying features. A remote station located within the cell of the first system communicates with the corresponding active base station. As the remote station moves into the coverage area of the repeater, the pilot signal of the repeater is identified and measured by the remote station and sent to the active base station. If the measured pilot signal is above a predetermined add threshold, the repeater can be added to the active set of the remote station and communications can be established concurrently with the active base station and the repeater. The first system

can transfer the communications to a base station of the second system using one of at least four embodiments.

In the first embodiment, the first system transfers the communications to the base station of the second system upon initiation of a soft handoff by the active base station of the first system with the repeater coverage area. This embodiment works well when the coverage area of the repeater is co-located within (a subset of) the cell of the second system. Thus, the first system is sufficiently assured that communications with the base station of the second system can be reliably established.

In the second embodiment, the first system transfers the communications to the base station of the second system if the pilot signal strength of the repeater, as measured by the remote station, exceeds a predetermined handoff threshold. The predetermined handoff threshold can be set higher than the predetermined add threshold which is used to add the repeater to the active set of the remote station. This embodiment works well even if the coverage area of the repeater is not co-located within the neighboring cell of the second system.

In the third embodiment, the first system transfers the communications to the base station of the second system if the base station of the first system is dropped from the active set of the remote station. In the exemplary embodiment, the remote station periodically measures the pilot signals of the active base station and the repeater and reports the measurements to the first system. If the pilot signal strength of the active base station of the first system, as measured by the remote station, is below a predetermined drop threshold, the base station is removed from the active set of the remote station. When this occurs, the first system can presume that the remote station has traveled sufficiently into the coverage area of the second system to initiate a handoff of the remote station to the second system.

In the fourth embodiment, the first system transfers the communications to the base station of the second system if the repeater of the first system is dropped from the active set of the remote station. This embodiment is particularly applicable in system designs wherein the coverage area of the repeater is inclosed within the coverage area of the second system (e.g., an AMP system) and it is desirable to handoff to this second system.

And in the fifth embodiment, the first system transfers the communications to the base station of the second system if the active base station and repeater of the first system are both dropped from the active set

of the remote station. When the pilot signal strength of both the active base station and repeater of the first system falls below the predetermined drop threshold, the first system can presume that the remote station has traveled outside the coverage range of the first system. Thus, a handoff of the remote station to the second system is attempted.

BRIEF DESCRIPTION OF THE DRAWINGS

The features, objects, and advantages of the present invention will become more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout and wherein:

FIG. 1 is a diagram of an exemplary communication system comprising a plurality of base stations and a repeater in communication with a remote station;

FIG. 2 is a block diagram of an exemplary forward link transmission and receiving subsystem;

FIG. 3 is a block diagram of an exemplary channel element within the base station; and

FIG. 4 is block diagram of an exemplary demodulator within the remote station;

FIGS. 5A-5B are block diagrams of an exemplary repeater communicating through an over-the-air link and a transmission line link, respectively; and

FIGS. 6A-6C are three exemplary diagrams of the coverage provided by a base station and a repeater of two communication systems.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the figures, FIG. 1 represents an exemplary communication system of the present invention which comprises multiple base stations 4 in communication with multiple remote stations 6 (only one remote station 6 is shown for simplicity). System controller 2 connects to all base stations 4 in the communication system, the public switched telephone network (PSTN), and system controllers of other communication systems. System controller 2 coordinates the communication between users

connected to the PSTN and other systems and users on remote stations 6. Each base station 4 can provide communications through zero or more repeater 8 which is used to retransmit or rebroadcast the forward link signal to remote station 6 and to receive the reverse link signal from remote station 6. Repeater 8 can be connected to base station 4 through a terrestrial radio link or other transmission links, such as a fiber optic link or transmission lines. Communications from base stations 4 to remote station 6 occurs on the forward link through signal paths 10 and communications from remote station 6 to base stations 4 occurs on the reverse link through signal paths 12.

A block diagram of an exemplary forward link transmission and receiving hardware is shown in FIG. 2. Within base station 4, data source 110 contains the data to be transmitted to remote station 6. In the exemplary embodiment, the data is provided to channel element 112 which partitions the data, CRC encodes the data, and inserts code tail bits as required by the system. In the exemplary embodiment, channel element 112 then convolutionally encodes the data, CRC parity bits, and code tail bits, interleaves the encoded data, scrambles the interleaved data with the user long PN sequence, and covers the scrambled data with a Walsh sequence. The traffic channel and pilot channel data corresponding to each sector is combined and provided to a modulator and transmitter (MOD AND TMTR) 114 (only one is shown in FIG. 2 for simplicity). Each modulator and transmitter 114 spreads the covered data with the short PN sequences. In the exemplary embodiment, the offset of the short PN sequences for each modulator and transmitter 114 is selected to be unique from those of neighboring modulators and transmitters. The spread data is then modulated with the in-phase and quadrature sinusoids, and the modulated signal is filtered, upconverted, and amplified. The forward link signal is transmitted on forward link 10 through antenna 116.

At remote station 6, the forward link signal is received by antenna 132 and provided to receiver (RCVR) 134. Receiver 134 filters, amplifies, downconverts, quadrature demodulates, and quantizes the signal. The digitized data is provided to demodulator (DEMOD) 136 which despreads the data with the short PN sequences, decovers the despread data with the Walsh sequence, and derotates the decovered data with the recovered pilot signal. The derotated data from different correlators within demodulator 136 are combined and descrambled with the user long PN sequence. The descrambled (or demodulated) data is provided to decoder 138 which

performs the inverse of the encoding performed within channel element **112**. The decoded data is provided to data sink **140**.

The forward link signal processing described above is further detailed in the aforementioned U.S. Patent Nos. 4,901,307 and 5,103,459. These patents also describe the reverse link signal processing which is not shown in FIG. 2 for simplicity. The present invention can also be applied to other communication systems, such as the system described in U.S. Patent Application Serial No. PA496, entitled "METHOD AND APPARATUS FOR HIGH RATE PACKET DATA TRANSMISSION", filed November 3, 1997, assigned to the assignee of the present invention and incorporated by reference herein.

A block diagram of an exemplary channel element **112** is shown in FIG. 3. In the exemplary embodiment, channel element **112** comprises at least one traffic channel **212** and at least one pilot channel **232**. Within each traffic channel **212**, CRC encoder **214** receives the traffic data, performs CRC encoding, and can insert a set of code tail bits (e.g., in accordance with the IS-95 standard). The CRC encoded data is provided to convolutional encoder **216** which encodes the data with a convolutional code. In the exemplary embodiment, the convolutional code is specified by the IS-95 standard. The encoded data is provided to interleaver **218** which reorders the code symbols within the encoded data. In the exemplary embodiment, interleaver **218** is a block interleaver which reorders the code symbols within blocks of 20 msec of encoded data. The interleaved data is provided to multiplier **220** which scrambles the data with the user long PN sequence. The long PN sequence is identical to that assigned to the remote station for which the communications is destined. The scrambled data is provided to multiplier **222** which covers the data with the Walsh sequence assigned to this traffic channel. The covered data is provided to gain element **224** which scales the data such that the required energy-per-bit-to-noise E_b/I_0 ratio is maintained at the destination remote station while minimizing transmit power. The scaled data is provided to switch **230** which directs the data from the traffic channels **212** to the proper summer **240**. Each summer **240** sums the signals from all traffic channels **212** and pilot channel **232** designated for that particular sector. The resultant signal from each summer **240** is provided modulator and transmitter **114** which functions in the manner described above.

Channel element **112** comprises at least one pilot channel **232**. The number of pilot channels **232** required is dependent on system requirements. In the exemplary embodiment, each sector is associated with

a pilot signal having the same Walsh cover (e.g., Walsh code 0) but a short PN offset which is unique from those of neighboring sectors. In the alternative embodiment, each sector can be associated with a pilot signal having the same short PN offset but a Walsh cover which is unique from those of neighboring sectors. Other unique identifying features can be used to distinguish the signals of different sectors and are within the scope of the present invention.

For each pilot channel **232**, the pilot data is provided to multiplier **234** which covers the data with a pilot Walsh sequence. In the exemplary embodiment, the pilot data for all pilot channels **232** are identical and comprises the all ones sequence. The covered pilot data is provided to gain element **236** which scales the pilot data with a scaling factor to maintain the required pilot signal level. The scaled pilot data is provided to switch **230** which directs the data from pilot channel **232** to the proper summer **240**. In the exemplary embodiment, the spreading with the corresponding short PN sequences is performed within modulator and transmitter **114**.

The hardware as described above is one of many embodiments which can be used by a single base station to provide coverage to multiple sectors. Another method and system for adaptive sectorized transmission are disclosed in U.S. Patent Application Serial No. 08/495,382, entitled "DYNAMIC SECTORIZATION IN A SPREAD SPECTRUM COMMUNICATION SYSTEM", filed June 27, 1995, assigned to the assignee of the present invention and incorporated by reference herein. Yet another method and system for transmission to particularized areas are described in the aforementioned U.S. Patent Application No. PA446. Other hardware architectures can also be designed to perform the functions described herein. These various architectures are within the scope of the present invention.

A block diagram of an exemplary demodulator within remote station **6** is shown in FIG. 4. The forward link signal is received by antenna **132** and provided to receiver **134** which processes the signal in the manner described above. The digitized I and Q data is provided to demodulator **136**. Within demodulator **136**, the data is provided to at least one correlator **310**. Each correlator **310** processes a different multipath component of the received signal. Within correlator **310**, the data is provided to short PN despreader **320** which despreads the I and Q data with the short PN sequences to obtain the despread I and Q data. The short PN despreading is the inverse of the spreading performed by the short PN spreader within modulator and transmitter **114**.

The despread I data is provided to multipliers **322a** and pilot correlators **326a** and the despread Q data is provided to multipliers **322b** and pilot correlators **326b**. Multipliers **322a** and **322b** multiply the I and Q data, respectively, with the Walsh sequence (Wx) assigned to that correlator **310**. The I and Q data from multipliers **322a** and **322b** is provided to accumulators (ACC) **324a** and **324b**, respectively. In the exemplary embodiment, accumulators **324** accumulate the data over a 64-chip interval, the length of the Walsh sequence. The decovered I and Q data from accumulators **324** is provided to dot product circuit **328**. Pilot correlators **326a** and **326b** decover the I and Q data with the pilot Walsh sequence (PWy) assigned to that correlator **310** and filter the decovered pilot signal. The filtered pilot is provided to dot product circuit **328** which computes the dot product of the two vectors (the pilot and data) in a manner known in the art. An exemplary embodiment of dot product circuit **328** is described in detail in U.S. Patent No. 5,506,865, entitled "PILOT CARRIER DOT PRODUCT CIRCUIT", assigned to the assignee of the present invention and incorporated by reference herein. Dot product circuit **328** projects the vector corresponding to the decovered data onto the vector corresponding to the filtered pilot, multiplies the amplitude of the vectors, and provides a signed scalar output to combiner **330**. Combiner **330** combines the outputs from correlators **310** which have been assigned to demodulate the received signal and routes the combined data to long PN despreader **332**. Long PN despreader **332** despreads the data with the long PN sequence and provides the demodulated data to decoder **138**.

The pilot signal strength for a particular correlator **310** can be computed from the filtered pilot from pilot correlators **326a** and **326b**. In addition, the pilot signal strength measurements can be filtered to provide a more reliable measurement. A method and apparatus for performing pilot signal measurement are described in U.S. Patent Application Serial No. 08/722,763, entitled "METHOD AND APPARATUS FOR MEASURING LINK QUALITY IN A SPREAD SPECTRUM COMMUNICATION SYSTEM", filed September 27, 1996, assigned to the assignee of the present invention and incorporated by reference herein.

In many communication systems, repeaters are employed to improve coverage and increase capacity. A repeater receives a signal from a source device, amplifies the signal, and retransmits or rebroadcasts the signal to a destination device. Generally, the repeater provides two-way retransmission or rebroadcast of the forward and reverse link signals between communicating devices. Typically, the repeater provides signal

conditioning (e.g., amplification, filtering, and possibly frequency conversion) but does not provide signal processing or control.

A block diagram of an exemplary repeater is shown in FIGS. 5A and 5B. In FIG. 5A, repeater **8a** communicates with the base station through terrestrial or satellite link **410**. Link **410** can be a terrestrial or microwave link from a source base station, or a satellite link from a communication satellite (such as a GLOBALSTAR communication satellite). The forward link signal from the base station is received by donor antenna **412** and provided to duplexer **414**. Duplexer **414** directs the forward link signal to amplifier (AMP) **416** which amplifies the signal. Filtering and/or frequency conversion can also be provided, although this is not shown in FIG. 5A for simplicity. The amplified signal is routed through duplexer **418** and transmitted to the remote stations through server antenna **420**. Serving antenna **420** also receives the reverse link signal from the remote stations. The reverse link signal is routed through duplexer **420** and provided to amplifier (AMP) **422** which amplifies the signal. Again, filtering and/or frequency conversion can also be provided but is not shown in FIG. 5A for simplicity. The amplified signal is routed through duplexer **414** and transmitted to the base station from antenna **412**.

Repeater **8b** as shown in FIG. 5B operates in the same manner as that of repeater **8a** in FIG. 5A. However, repeater **8b** interfaces with the base station through transmission line link **424**, which can comprise a fiber optic link, a coaxial link, or other links.

The partition of a cell into multiple sectors provides many benefits in CDMA communication systems. First, capacity can be improved since the traffic channels (e.g., Walsh codes) among the various sectors can be reused. Second, reliability can also be improved through the use of soft handoff with two or more sectors.

In the exemplary CDMA communication system disclosed in the aforementioned U.S. Patent Application Serial No. 08/495,382, the base station can be configured to provide communications through a single sector or multiple sectors. The coverage area of the base station (or the cell) can be partitioned into multiple sectors. The communications between a remote station and the base station can occur through one or more sectors. Each sector has the attributes of a cell (e.g., each sector having its own set of traffic channels and its own pilot signal), except that the communication through the various sectors of the cell are coordinated by a common base station. For IS-95 systems, each sector is associated with a different offset of the short PN spreading codes. Thus, by measuring the short PN offset of the

pilot signal transmitted by a particular sector, the identity of that sector can be determined.

In the exemplary embodiment, the base station is configured to provide coverage to two or more sectors. One or more sectors can be associated with the coverage area surrounding the base station. The remaining sectors can be associated with repeaters which are placed at the boundary of the cell. For example, the cell can be partitioned into two sectors. The base station can then be operated to provide coverage to three sectors, two sectors associated with the cell within which the base station is located and one sector associated with a repeater.

A first exemplary diagram of the coverage provided by a base station and a repeater of two communication systems is shown in FIG. 6A. In FIG. 6A, base station **4** is operated to provided coverage to two sectors. One sector is associated with cell **22**. The second sector is associated with repeater **8** which provides coverage to coverage area **26**. In the exemplary embodiment, both cell **22** and coverage area **26** are operated at the same frequency and overlaps such that a remote station moving along road **30** can be in soft handoff when located within shaded region **30**. Base station **4** and repeater **8** are part of a first communication system.

In the exemplary diagram shown in FIG. 6A, communications in the areas adjacent to cell **22** is provided by a second communication system. This second communication system can be another CDMA system operating at a different frequency or a system of an alternative communication technology, such as AMPS. Base station **14** of the second system provides coverage to cell **24**. Similar to the first system, base station **14** can also be operated in a multi-sector mode to provide coverage to adjoining coverage area **28** through repeater **18**. Note, in this example, the coverage area **26** is co-located within cell **24**.

A second exemplary diagram of the coverage provided by a base station and a repeater is shown in FIG. 6B. In FIG. 6B, coverage area **26** overlaps cell **24** but is not completely contained within cell **24** (as is the case in FIG. 6A). Coverage area **26** can be used to bridge the coverage between the first and second systems. Repeater **18** is not shown in FIG. 6B for simplicity.

A third exemplary diagram of the coverage provided by a base station and a repeater is shown in FIG. 6C. In FIG. 6C, coverage area **26** overlaps cell **24** but is not co-located within cell **24**. Furthermore, cells **22** and **24** are non-adjoining such that handoff between base station **4** to base station **14** is not possible without an intermediate handoff to repeater **8**. Again, repeater **18** is not shown in FIG. 6C for simplicity.

In the exemplary embodiment, the first system has a priori knowledge that coverage area **26** overlaps cells **22** and **24**. The first system also has a priori knowledge that base station **14** is controlled by the second system. In the exemplary embodiment, the first system is connected to the second system and can initiate a handoff of a remote station from the first system to the second system.

In the present invention, as the remote station moves from the first system to the second system, and vice versa, repeaters can be used to initiate a handoff of the remote station between the two systems. Referring to FIG. 6A, assume that the remote station moves along road **30** from left to right. Initially, the remote station is located in cell **22** and communicates with base station **4**. As the remote station travels into the shaded region **30**, the remote station also receives the pilot signal from repeater **8**. The remote station demodulates the pilot signal from repeater **8**, determines the identity of the new pilot, and reports the pilot signal strength and identity (e.g., the PN offset or the Walsh code of the pilot signal) to base station **4**. Base station **4** compares the reported pilot signal strength against a predetermined add threshold and can add repeater **8** to the active set of the remote station if the pilot signal strength exceeds the predetermined add threshold. The active set comprises the list of base stations (and/or repeaters) through which active communication is established. Base station **4** can then direct soft handoff of the remote station in accordance with the method described in the aforementioned U.S. Patent Nos. 5,101,501 and 5,267,261. In the present invention, handoff of the communications between the remote station and base station **4** to base station **14** can be accomplished in one of at least four embodiments.

In the first embodiment, the first system initiates a handoff of the communications between the remote station and base station **4** to base station **14** upon initiation of a soft handoff with repeater **8**. Referring to FIG. 6A, coverage area **26** is co-located within cell **24**. This can be ensured during the system planning stage and by proper placements of the base stations and repeaters. In this case, the first system is reasonably assured that a remote station which is in soft handoff with repeater **8** is also within the coverage area of base station **14**. This information can be used to initiate the handoff to base station **14** when the remote station is within the coverage area of repeater **8**.

In the second embodiment, the first system initiates a handoff of the communications between the remote station and base station **4** to base station **14** upon measurement of a sufficient pilot signal strength from

repeater 8. In this embodiment, base station 4 initiates handoff with repeater 8 when the reported pilot signal strength of repeater 8, as measured by the remote station, is above the predetermined add threshold as described above. However, since coverage area 26 may not be co-located within cell 22 as illustrated by FIGS. 6B-6C, the first system does not immediately initiate handoff of the communications from base station 4 to base station 14 upon initiation of a handoff with repeater 8, since doing so may result in disconnection of the communications. Instead, the remote station continues to measure the pilot signal strength from repeater 8 and reports the measurements to base station 4. Base station 4 can compare the pilot measurements against a predetermined handoff threshold which is set higher than the predetermined add threshold. The first system initiates the handoff of the communications between the remote station and base station 4 to base station 14 when the reported pilot signal strength of repeater 8 is above the predetermined handoff threshold. The second embodiment works well for the coverage illustrated by FIGS. 6A-6B.

The predetermined handoff threshold can be set in accordance with measurements of the pilot signal strength throughout coverage area 26 (e.g., pilot signal strength measurement along road 30) or can be set in accordance with computation of the expected pilot signal strength (e.g., using effective radiated power (ERP) and r^4 propagation law, where r is the distance from repeater 8). As an example, the predetermined handoff threshold can be set 5 dB higher than that of the predetermined add threshold, although other values can be used based on system design and are within the scope of the present invention.

In the third embodiment, the first system initiates a handoff of the communications between the remote station and base station 4 to base station 14 when base station 4 is dropped from the active set of the remote station. In the exemplary embodiment, the remote station periodically measures the pilot signals of the base stations and repeaters within its active set and reports these measurements to the active base stations. The active base stations compare the pilot measurements against a predetermined drop threshold. If a pilot measurement is below the predetermined drop threshold, the base station corresponding to this pilot signal is removed from the active set of the remote station as described in the aforementioned U.S. Patent Nos. 5,101,501 and 5,267,261. In this embodiment, if the pilot signal from base station 4 is below the predetermined drop threshold, the first system can presume that the remote station has traveled well within cell 24. Thus, the first system initiates the handoff of the communications

between the remote station and base station 4 to base station 14 when base station 4 is dropped from the active set of the remote station. The third embodiment also works well for the coverage illustrated by FIGS. 6A-6B.

In the forth embodiment, the first system initiates a handoff of the communications between the remote station and base station 4 to base station 14 when repeater 8 is dropped from the active set of the remote station. In this embodiment, communications between the remote station and repeater 8 is maintained for as long as possible. However, if the pilot signal strength of repeater 8 is below the predetermined drop threshold, the first system presumes that the remote station is within the coverage area of the second system. Thus, the first system initiates the handoff of the communications between the remote station and base station 4 to base station 14 when repeater 8 is dropped from the active set of the remote station. The fourth embodiment works well for the coverage illustrated by FIG. 6A.

In the fifth embodiment, the first system initiates a handoff of the communications between the remote station and base station 4 to base station 14 when both base station 4 and repeater 8 are dropped from the active set of the remote station. In this embodiment, communications between the remote station and base station 4 and/or repeater 8 is maintained for as long as possible. However, if the pilot signal strength of base station 4 and repeater 8 is below the predetermined drop threshold, the first system presumes that the remote station has traveled beyond the coverage area of the first system. Thus, the first system initiates the handoff of the communications between the remote station and base station 4 to base station 14 when both base station 4 and repeater 8 are dropped from the active set of the remote station. The fifth embodiment works well for the coverage illustrated by FIGS. 6A-6C.

The second, third, and fifth embodiments described above provide hysteresis which minimizes the 'ping-ponging' of handoffs between two systems. In the second embodiment, the hysteresis is provided by the difference between the predetermined add threshold and the predetermined handoff threshold. And in the third and fifth embodiments, the hysteresis is provided by the difference between the predetermined add threshold and the predetermined drop threshold of the base station and the repeater.

Although the handoff described above occurs during active communication between the remote station and the base station, this handoff to the second system can also occur while the remote station is idle. As the remote station travels along road 30, the pilot signal of repeater 8 can

be measured. In the first embodiment for idle-mode handoff, the remote station reports the pilot measurements to the first system. The first system can direct the handoff to the second system using any one of the embodiments described above. The handoff can be accomplished through interface messages which are transmitted between the base stations and the remote station. In the second embodiment for idle-mode handoff, the remote station monitors for a global redirection message which is broadcast over the coverage area of the repeater. The global redirection message can direct the remote station to a new frequency or another system (e.g., an AMP system). In the third embodiment for idle-mode handoff, the remote station monitors for an extended neighbor list message which is broadcast over the coverage area of the repeater. The extended neighbor list message can indicate that the only neighbors for this remote station are on another frequency or another system. The extended neighbor list message is described in the CDMA standard entitled "ANSI J-STD-008 : Personal Station-Base Station Compatibility Requirements for 1.8 to 2.0 GHz Code Division Multiple Access (CDMA) Personal Communications Systems". Other embodiments to perform handoff in idle mode can be contemplated and are within the scope of the present invention.

Although only one repeater is shown in FIGS. 6A-6C for the first system, multiple repeaters can be employed. Repeaters can be employed to extend the coverage area from which handoff can be performed. Furthermore, repeaters can be employed to link non-adjoining coverage areas of the two systems (e.g., repeaters connected in serial manner). The system initiating the handoff has a priori knowledge of the particular repeater which overlaps the neighboring system. The system uses this information and the report of the identity and/or pilot signal strength of this repeater to initiate the handoff.

The present invention can also be practiced using a pilot beacon which transmits only the pilot signal (and no traffic channels). The use of the pilot beacon can be used in conjunction with the first three embodiments described above. The pilot beacon produces minimal interference to the surrounding coverage areas while providing the necessary pilot identification and signal strength measurements. In general, any signal transmitted from the repeater or pilot beacon can be used assist with the handoff process.

The previous description of the preferred embodiments is provided to enable any person skilled in the art to make or use the present invention. The various modifications to these embodiments will be readily apparent to

those skilled in the art, and the generic principles defined herein may be applied to other embodiments without the use of the inventive faculty. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

I CLAIM:

CLAIMS

1. A method for performing handoff of a remote station from a first base station to a second base station comprising the steps of :

measuring a signal strength measurement of a signal from a repeater at the remote station;

comparing the signal strength measurement of the repeater against a predetermined add threshold; and

initiating the handoff in response to a result of the comparing step.

2. The method of claim 1 wherein the signal from the repeater is a pilot signal.

3. The method of claim 2 wherein the repeater transmit a pilot beacon.

4. The method of claim 2 wherein the pilot signal from the repeater is identified by an offset of short PN spreading sequences unique from the offset of the short PN spreading sequences of the first base station.

5. The method of claim 1 wherein the pilot signal from the repeater is identified by a Walsh cover unique from the Walsh cover of the pilot signal of the first base station.

6. The method of claim 1 wherein a coverage area of the repeater overlaps a coverage area of the first base station.

7. The method of claim 1 wherein a coverage area of the repeater overlaps a coverage area of the second base station.

8. The method of claim 1 wherein a coverage area of the repeater is co-located within a coverage area of the second base station.

9. The method of claim 1 wherein the first base station and the repeater both operate on a common frequency.

10. The method of claim 1 wherein the second base station operates on a frequency different from the frequency of the repeater.

11. The method of claim 1 wherein the repeater communicates with the first base station through a terrestrial link.

12. The method of claim 1 wherein the repeater communicates with the first base station through a transmission line link.

13. The method of claim 1 wherein the first base station is operated to provide coverage to a plurality of sectors, on sector associated with the repeater.

14. The method of claim 1 wherein the initiating the handoff step is performed if the signal strength measurement of the repeater exceeds the predetermined add threshold.

15. The method of claim 1 further comprising the step of:

comparing the signal strength measurement of the repeater against a predetermined handoff threshold; and

wherein the initiating the handoff step is performed if the signal strength measurement of the repeater exceeds the predetermined handoff threshold.

16. The method of claim 15 wherein the predetermined handoff threshold is set higher than the predetermined add threshold.

17. The method of claim 15 wherein the predetermined handoff threshold is set in accordance with signal strength measurements throughout a coverage area of the repeater.

18. The method of claim 15 wherein the predetermined handoff threshold is set in accordance with computed signal strength throughout a coverage area of the repeater.

19. The method of claim 1 further comprising the steps of:

measuring a signal strength measurement of a signal from the first base station at the remote station;

comparing the signal strength measurement of the first base station against a predetermined drop threshold; and

wherein the initiating the handoff step is performed if the signal strength measurement of the base station is below the predetermined drop threshold.

20. The method of claim 19 wherein the initiating the handoff step is performed if the signal strength measurement of the repeater and the signal strength measurement of the base station are below the predetermined drop threshold.

21. A system for performing handoff of a remote station from a first base station to a second base station comprising:

a repeater connected to the first base station for providing a signal to the remote station;

a first system controller connected to the first base station;

a second system controller connected to the second base station and to the first system controller; and

wherein the handoff is initiated by the first system controller based on measurement of the signal from the repeater at the remote station.

22. The system of claim 21 wherein the signal from the repeater is a pilot signal.

23. The system of claim 22 wherein the pilot signal from the repeater is identified by an offset of short PN spreading sequences unique from the offset of the short PN spreading sequences of the first base station.

24. The system of claim 21 wherein a coverage area of the repeater overlaps a coverage area of the second base station.

25. The system of claim 21 wherein the first base station and the repeater both operate on a common frequency.

26. The system of claim 21 wherein the second base station operates on a frequency different from the frequency of the repeater.

27. The system of claim 21 wherein the repeater is connected to the first base station through a terrestrial link.

28. The system of claim 21 wherein the repeater is connected to the first base station through a transmission line link.

29. The system of claim 21 wherein the handoff is initiated if the signal strength measurement of the repeater exceeds a predetermined add threshold.

30. The system of claim 21 wherein the handoff is initiated if a signal strength measurement of the base station is below a predetermined drop threshold.

31. The system of claim 21 wherein the handoff is initiated if a signal strength measurement of the base station and the signal strength measurement of the repeater are below a predetermined drop threshold.

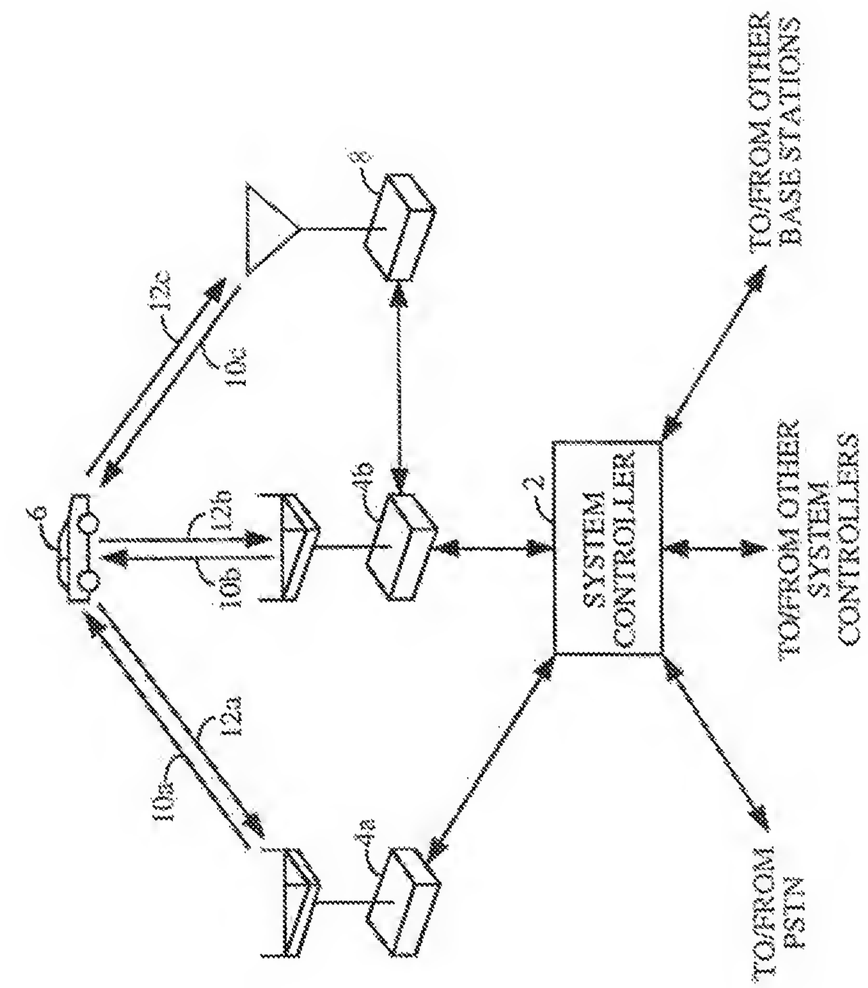
6
10a
12a
10b
12b
10c
12c
4a
4b
8
2
SYSTEM CONTROLLER
TO/FROM PSTN
TO/FROM OTHER SYSTEM CONTROLLERS
TO/FROM OTHER BASE STATIONS

FIG. 1

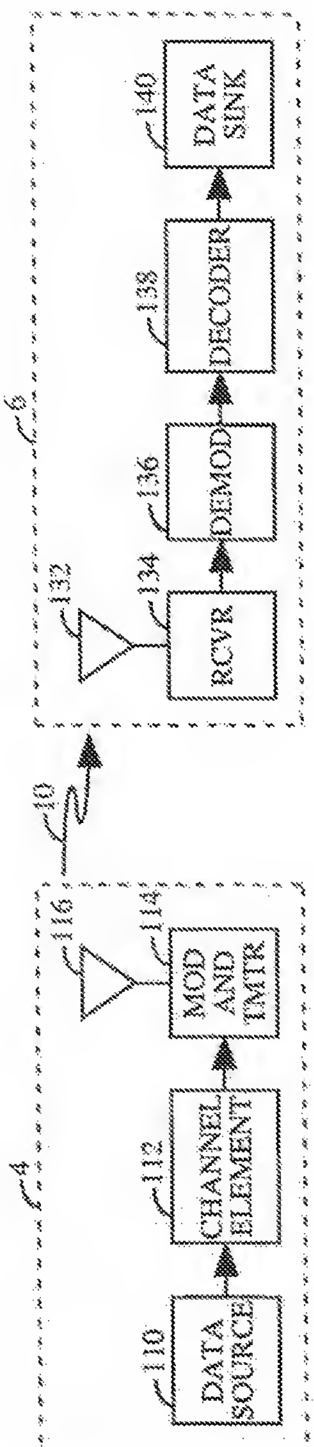
4
110
DATA SOURCE
112
CHANNEL ELEMENT
114
MOD AND TMTR
116
10
6
132
134
RCVR
136
DEMOD
138
DECODER
140
DATA SINK

FIG. 2

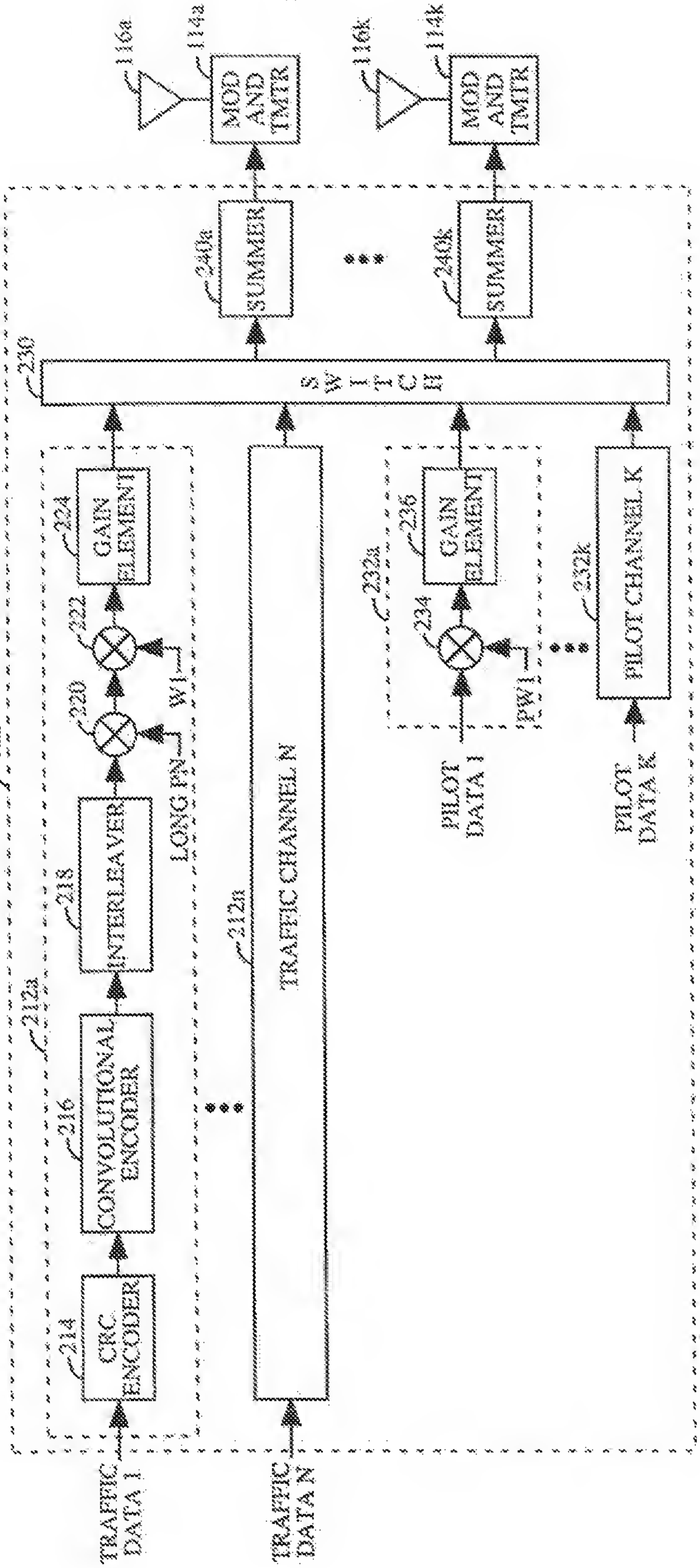
112
212a
TRAFFIC DATA 1
214
CRC ENCODER
216
CONVOLUTIONAL ENCODER
218
INTERLEAVER
220
LONG PN
222
W1
224
GAIN ELEMENT
212n
TRAFFIC DATA N
TRAFFIC CHANNEL N
232a
PILOT DATA 1
234
PW1
236
GAIN ELEMENT
232k
PILOT DATA K
PILOT CHANNEL K
230
SWITCH
240a
SUMMER
240k
SUMMER
114a
MOD AND TMTR
116a
114k
MOD AND TMTR
116k

FIG. 3

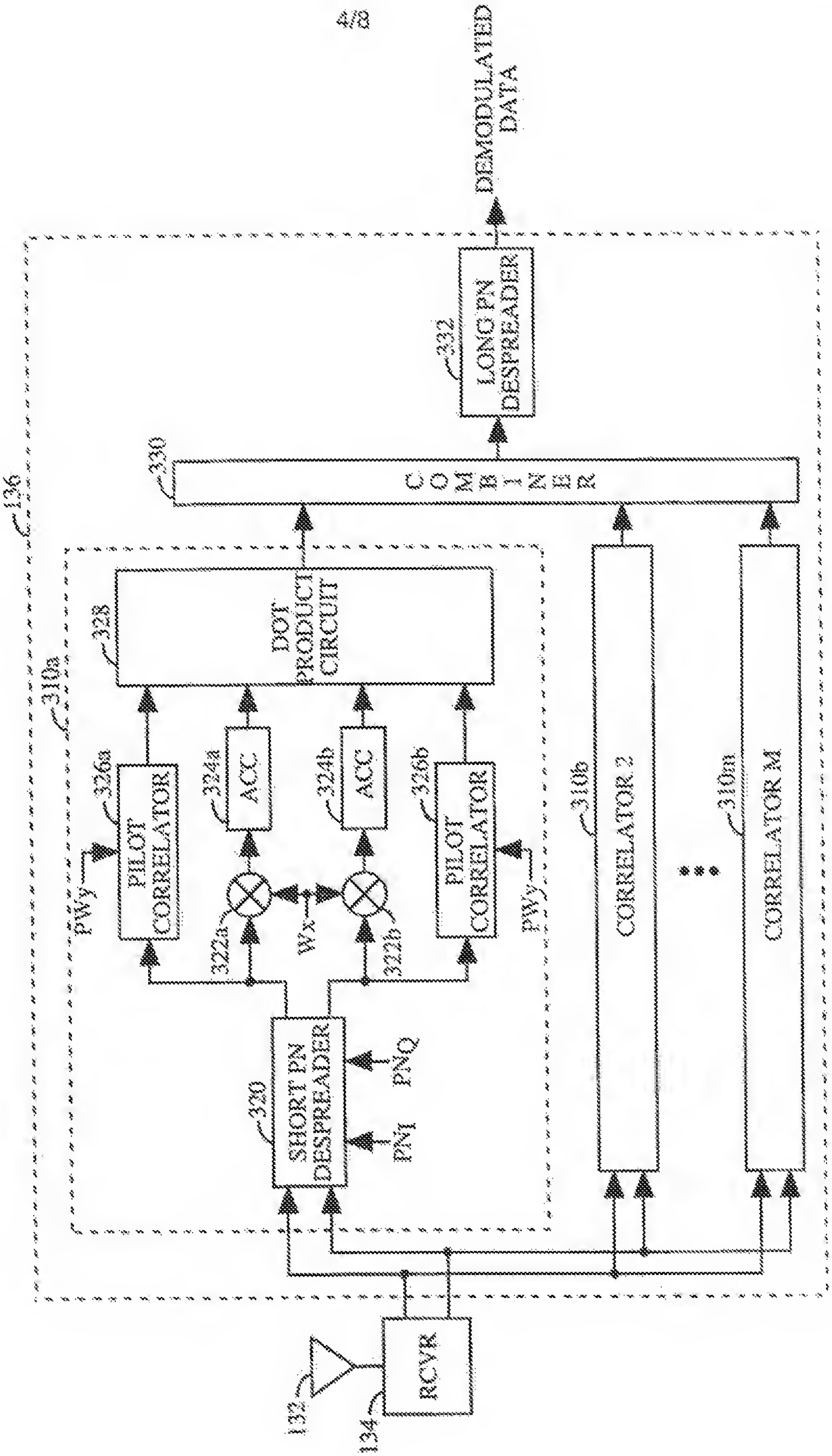
132
134
RCVR
136
310a
320
SHORT PN DESPREADER
PNI
PNQ
322a
322b
Wx
PWy
326a
PILOT CORRELATOR
326b
PILOT CORRELATOR
PWy
324a
ACC
324b
ACC
328
DOT PRODUCT CIRCUIT
310b
CORRELATOR 2
310m
CORRELATOR M
330
COMBINER
332
LONG PN DESPREADER
DEMODULATED DATA

FIG. 4

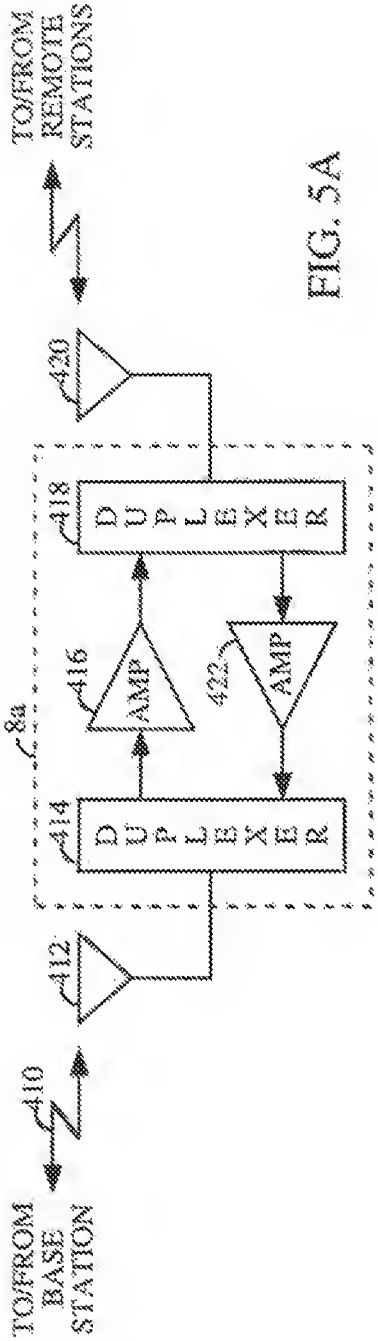
TO/FROM BASE STATION
410
412
414
DUPLEXER
8a
416
AMP
422
AMP
418
DUPLEXER
420
TO/FROM REMOTE STATIONS

FIG. 5A

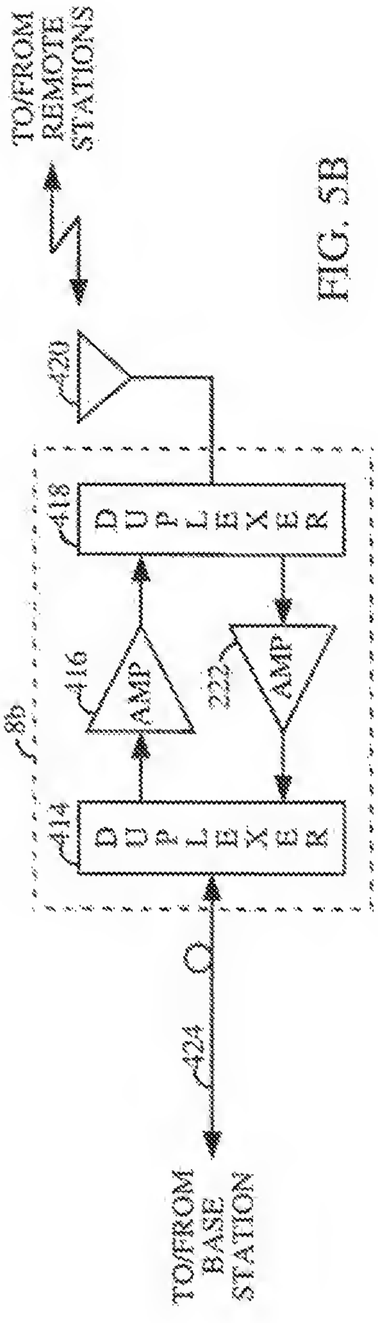
TO/FROM BASE STATION
424
414
DUPLEXER
8b
416
AMP
222
AMP
418
DUPLEXER
420
TO/FROM REMOTE STATIONS

FIG. 5B

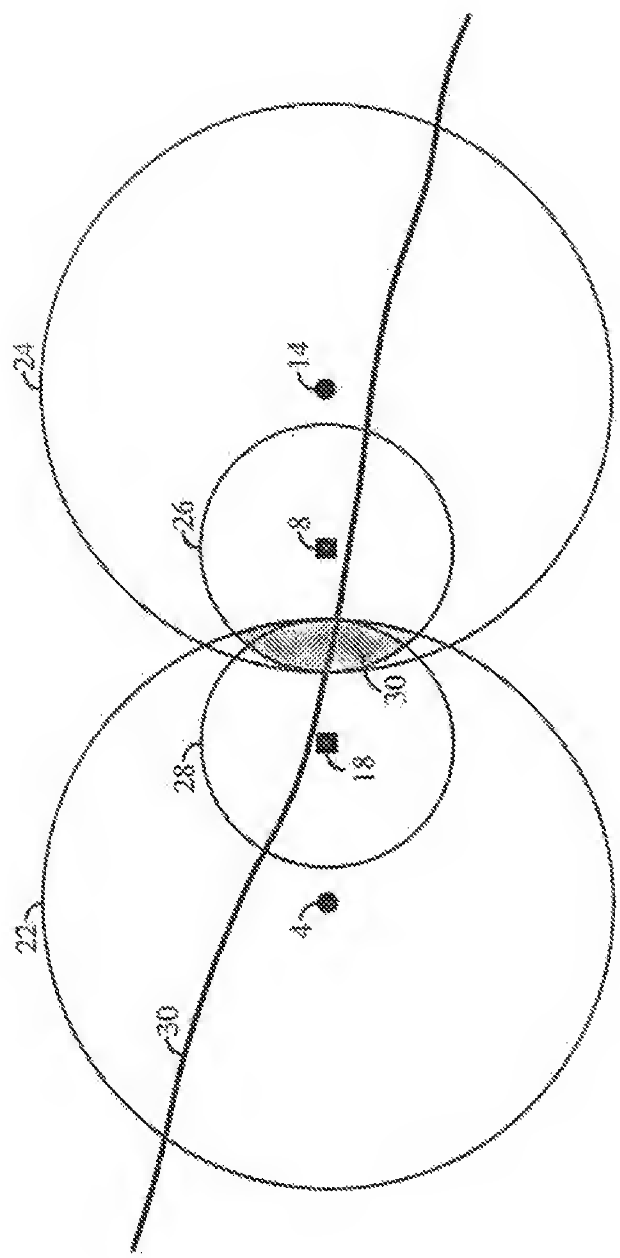

FIG. 6A

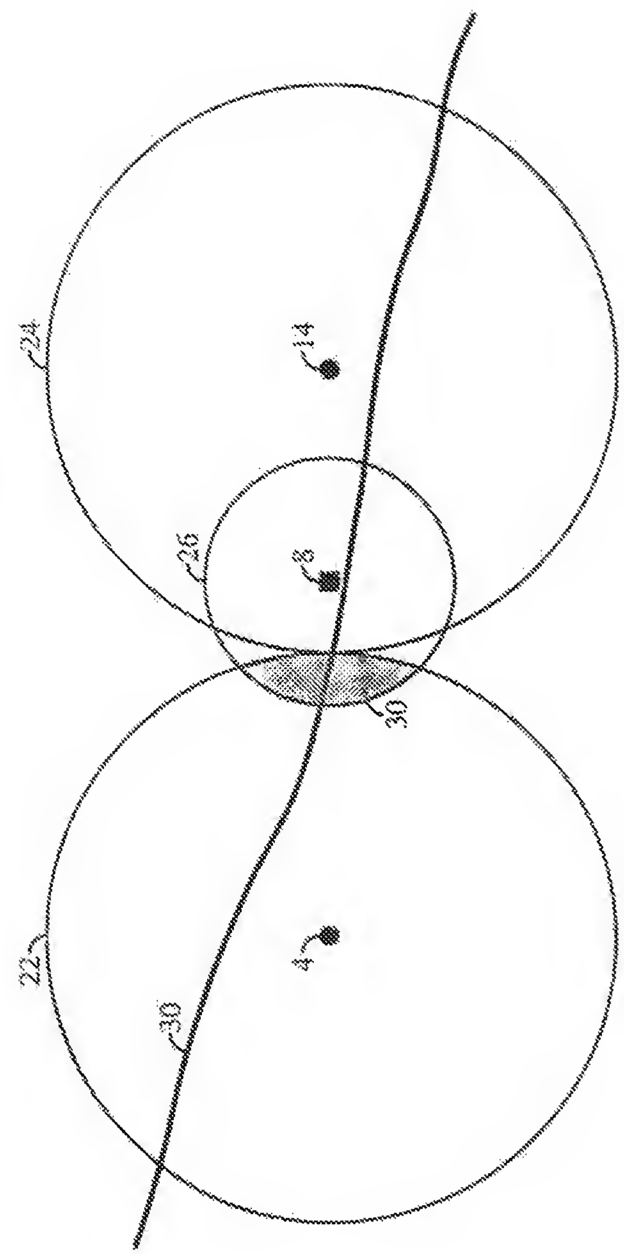

FIG. 6B

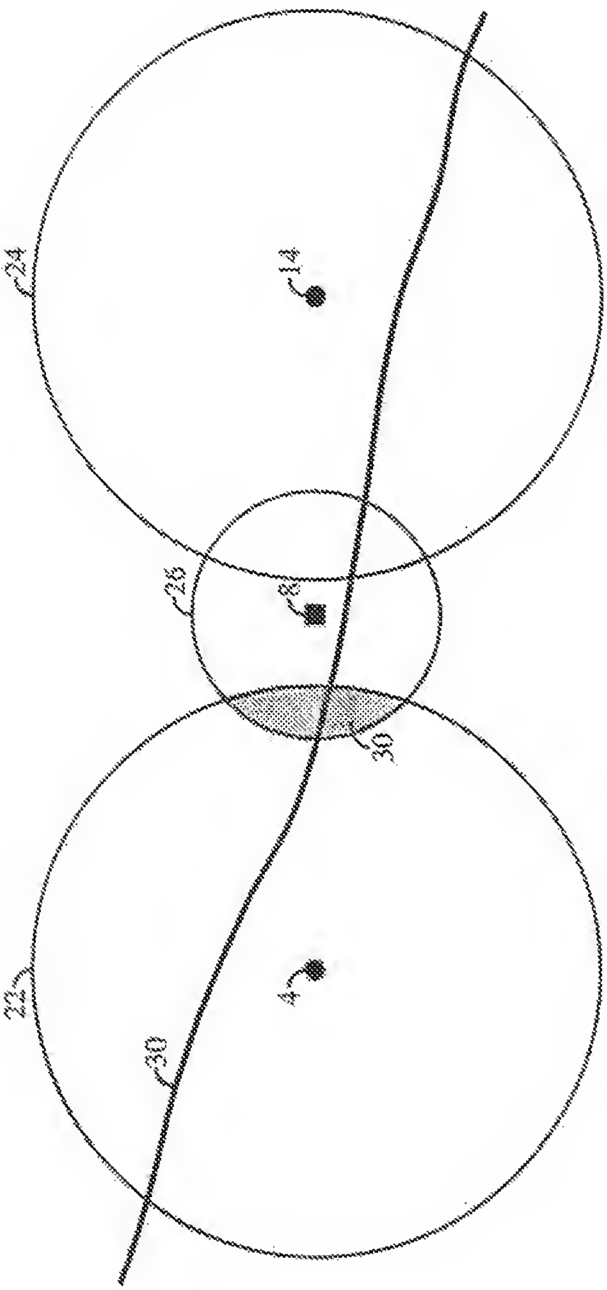

FIG. 6C

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 98/25219

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04Q7/38 H04Q7/36

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04Q H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 96 31078 A (QUALCOMM INC) 3 October 1996 see page 4, line 13 - line 39 see page 8, line 2 - page 10, line 8 see figures 1,2	1-15,19, 21-30
A	GB 2 253 324 A (ORION INDUSTRIES) 2 September 1992 see page 6, line 19 - page 7, line 12 see claims 1,11 see figure 1	1-31
A	WO 96 12380 A (QUALCOMM INC) 25 April 1996 see page 5, line 21 - page 6, line 30 see figure 3 see page 15, line 10 - page 16, line 10	1-31

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 March 1999	31/03/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Pecci, R

1

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	WO 97 08854 A (QUALCOMM INC) 6 March 1997 see page 7, line 35 - page 8, line 4 see page 12, line 14 - line 36	1-31

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 98/25219

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
WO 9631078	A	03-10-1996	US	5594718	A	14-01-1997
			AU	697734	B	15-10-1998
			AU	5432396	A	16-10-1996
			BR	9607948	A	14-07-1998
			CA	2216635	A	03-10-1996
			EP	0818117	A	14-01-1998
GB 2253324	A	02-09-1992	US	5218715	A	08-06-1993
			AU	650943	B	07-07-1994
			AU	1023792	A	23-07-1992
			CA	2059235	A	16-07-1992
			ES	2068064	A	01-04-1995
WO 9612380	A	25-04-1996	US	5697055	A	09-12-1997
			AU	3825695	A	06-05-1996
			ZA	9508574	A	23-05-1996
WO 9708854	A	06-03-1997	AU	1114697	A	19-03-1997
			EP	0847634	A	17-06-1998
			FI	980278	A	27-04-1998